

## **CLAIMS**

What is claimed is:

1. An analog-to-digital conversion system, comprising:  
a first A/D converter providing a first digital output according to a system  
5 analog input and according to a noise shaped first analog feedback signal; and  
a noise shaping system having less than N integrator amplifiers, the noise  
shaping system being coupled to the first A/D converter and providing the first  
analog feedback signal according to the first digital output, the first analog  
feedback signal being noise shaped by the noise shaping system to an order N  
10 with respect to a quantization error associated with the first A/D converter,  
wherein N is an integer greater than 1.
2. The analog-to-digital conversion system of claim 1, wherein  $N = 2$ .
- 15 3. The analog-to-digital conversion system of claim 2, wherein the first  
A/D converter is a flash analog-to-digital converter.
4. The analog-to-digital conversion system of claim 2, wherein the first  
A/D converter is a flash ADC providing a thermometer coded first digital output  
20 representative of the system analog input.
5. The analog-to-digital conversion system of claim 2, further  
comprising a digital decimation filter coupled with the first A/D converter and  
providing a multi-bit digital output according to the first digital output, the multi-bit  
25 digital output being representative of the system analog input.
6. The analog-to-digital conversion system of claim 2, wherein the  
noise shaping system comprises:  
a first DAC coupled with the first A/D converter, the first DAC providing an  
30 analog first DAC output according to the first digital output;

a delta sigma modulator coupled with the first DAC, the delta sigma modulator providing a second digital output according to a difference between the first DAC output and the system analog input; and

5 a digital error feedback system coupled with the delta sigma modulator, the digital error feedback system providing the first analog feedback signal to the first A/D converter according to the second digital output, the first analog feedback signal being noise shaped by the digital error feedback system to order N with respect to a quantization error associated with the delta sigma modulator.

10 7. The analog-to-digital conversion system of claim 6, wherein the delta sigma modulator comprises:

an integrator of order N-1 coupled with the first DAC, the integrator providing an analog integrator output according to the first DAC output, according to the system analog input, according to the first analog feedback signal, and  
15 according to an analog modulator feedback signal, the integrator having less than N integrator amplifiers;

a second A/D converter coupled with the integrator, the second A/D converter providing a second digital output according to the integrator output; and

20 a second DAC coupled with the second A/D converter, the second DAC providing the modulator feedback signal to the integrator according to the second digital output;

wherein the integrator output is noise shaped by the integrator to an order N-1 with respect to a quantization error associated with the second A/D converter.

25

8. The analog-to-digital conversion system of claim 7, wherein the noise shaping system further comprises an analog delay system coupled with the integrator and with the first A/D converter, the analog delay system providing an analog delayed integrator output signal to the integrator and to the first A/D  
30 converter.

9. The analog-to-digital conversion system of claim 7, wherein the digital error feedback system comprises:

a digital signal processing system coupled with the delta sigma modulator, the digital signal processing system providing a third digital output according to the second digital output, the third digital output being noise shaped by the digital signal processing system to order N with respect to a quantization error associated with the delta sigma modulator; and

a third DAC coupled with the digital signal processing system, the third DAC providing the first analog feedback signal to the first A/D converter according to the third digital output.

10. The analog-to-digital conversion system of claim 9, wherein at least one of the first DAC, the second DAC, and the third DAC comprises:

a switched capacitor system comprising a plurality of selectable capacitors providing an analog output corresponding to a digital input code using DAC elements selected according to the digital input code; and

a dynamic element matching system coupled with the switched capacitor system, wherein the dynamic element matching system varies the selection of capacitors.

11. The analog-to-digital conversion system of claim 6, wherein the digital error feedback system comprises:

a digital signal processing system coupled with the delta sigma modulator, the digital signal processing system providing a third digital output according to the second digital output, the third digital output being noise shaped by the digital signal processing system to order N with respect to a quantization error associated with the delta sigma modulator; and

a third DAC coupled with the digital signal processing system, the third DAC providing the first analog feedback signal to the first A/D converter according to the third digital output.

12. The analog-to-digital conversion system of claim 1, wherein the noise shaping system comprises:

a first DAC coupled with the first A/D converter, the first DAC providing an analog first DAC output according to the first digital output;

5 a delta sigma modulator coupled with the first DAC, the delta sigma modulator providing a second digital output according to a difference between the first DAC output and the system analog input; and

a digital error feedback system coupled with the delta sigma modulator, the digital error feedback system providing the first analog feedback signal to the first A/D converter according to the second digital output, the first analog feedback signal being noise shaped by the digital error feedback system to order N with respect to a quantization error associated with the delta sigma modulator.

13. The analog-to-digital conversion system of claim 12, wherein the delta sigma modulator comprises:

15 an integrator of order N-1 coupled with the first DAC, the integrator providing an analog integrator output according to the first DAC output, according to the system analog input, according to the first analog feedback signal, and according to an analog modulator feedback signal, the integrator having less than N integrator amplifiers;

20 a second A/D converter coupled with the integrator, the second A/D converter providing a second digital output according to the integrator output; and

a second DAC coupled with the second A/D converter, the second DAC providing the modulator feedback signal to the integrator according to the second digital output;

25 wherein the integrator output is noise shaped by the integrator to an order N-1 with respect to a quantization error associated with the second A/D converter.

30 14. The analog-to-digital conversion system of claim 13, wherein the noise shaping system further comprises an analog delay system coupled with the

integrator and with the first A/D converter, the analog delay system providing an analog delayed integrator output signal to the integrator and to the first A/D converter.

5            15.    The analog-to-digital conversion system of claim 13, wherein the digital error feedback system comprises:

             a digital signal processing system coupled with the delta sigma modulator, the digital signal processing system providing a third digital output according to the second digital output, the third digital output being noise shaped by the digital  
10    signal processing system to order N with respect to a quantization error associated with the delta sigma modulator; and

             a third DAC coupled with the digital signal processing system, the third DAC providing the first analog feedback signal to the first A/D converter according to the third digital output.

15            16.    The analog-to-digital conversion system of claim 15, wherein at least one of the first DAC, the second DAC, and the third DAC comprises:

             a switched capacitor system comprising a plurality of selectable capacitors providing an analog output corresponding to a digital input code using DAC  
20    elements selected according to the digital input code; and

             a dynamic element matching system coupled with the switched capacitor system, wherein the dynamic element matching system varies the selection of capacitors.

25            17.    The analog-to-digital conversion system of claim 12, wherein the digital error feedback system comprises:

             a digital signal processing system coupled with the delta sigma modulator, the digital signal processing system providing a third digital output according to the second digital output, the third digital output being noise shaped by the digital  
30    signal processing system to order N with respect to a quantization error associated with the delta sigma modulator; and

a third DAC coupled with the digital signal processing system, the third DAC providing the first analog feedback signal to the first A/D converter according to the third digital output.

5           18.    A noise shaping system for providing a noise shaped first analog feedback signal to a first A/D converter in an analog-to-digital conversion system, the noise shaping system comprising:

            a first DAC coupled with the first A/D converter, the first DAC providing an analog first DAC output according to a first digital output;

10           a delta sigma modulator coupled with the first DAC, the delta sigma modulator providing a second digital output according to a difference between the first DAC output and a system analog input; and

            a digital error feedback system coupled with the delta sigma modulator, the digital error feedback system providing the first analog feedback signal to the  
15           first A/D converter according to the second digital output.

            19.    The noise shaping system of claim 18, wherein the delta sigma modulator comprises less than N integrator amplifiers, and wherein the first analog feedback signal is noise shaped to order N with respect to a quantization  
20           error associated with the first A/D converter, wherein N is an integer greater than 1.

            20.    The noise shaping system of claim 18, wherein the delta sigma modulator comprises:

25           an integrator coupled with the first DAC, the integrator providing an analog integrator output according to the first DAC output, according to the system analog input, according to the first analog feedback signal, and according to an analog modulator feedback signal, the integrator having N-1 integrator amplifiers;

            a second A/D converter coupled with the integrator, the second A/D  
30           converter providing a second digital output according to the integrator output; and

a second DAC coupled with the second A/D converter, the second DAC providing the modulator feedback signal to the integrator according to the second digital output;

wherein the integrator output is noise shaped by the integrator to an order  
5 N-1 with respect to a quantization error associated with the second A/D converter.

21. The noise shaping system of claim 20, wherein the noise shaping system further comprises an analog delay system coupled with the integrator and  
10 with the first A/D converter, the analog delay system providing an analog delayed integrator output signal to the integrator and to the first A/D converter.

22. The noise shaping system of claim 20, wherein the digital error feedback system comprises:

15 a digital signal processing system coupled with the delta sigma modulator, the digital signal processing system providing a third digital output according to the second digital output, the third digital output being noise shaped by the digital signal processing system to order N with respect to a quantization error associated with the delta sigma modulator; and

20 a third DAC coupled with the digital signal processing system, the third DAC providing the first analog feedback signal to the first A/D converter according to the third digital output.

23. A noise shaping system for providing a noise shaped analog  
25 feedback signal to a first A/D converter in an analog-to-digital conversion system, the noise shaping system comprising:

a DAC receiving a first digital output from the first A/D converter, the DAC providing an analog DAC output according to the first digital output;

a second A/D converter coupled with the DAC, the second A/D converter  
30 comprising less than N integrator amplifiers and providing a second digital output

according to a difference between the DAC output and a system analog input,  $N$  being an integer greater than 1; and

a digital error feedback system coupled with the second A/D converter, the digital error feedback system providing a noise shaped analog feedback signal to the first A/D converter according to the second digital output, wherein the first analog feedback signal is noise shaped by the digital error feedback system to order  $N$  with respect to a quantization error associated with the first A/D converter.

24. A second order noise shaping system for providing a noise shaped analog feedback signal to an A/D converter in an analog-to-digital conversion system, the noise shaping system comprising:

a first order integrator having a single amplifier; and

a digital error feedback system comprising a digital signal processing system, the digital error feedback system providing an analog feedback signal to the A/D converter with second order noise shaping with respect to a quantization error associated with the A/D converter.